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TERATOGENIC EFFECTS OF MICROWAVE RADIATION

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Subsequent experiments were performed on pregnant CF-1 mice at 0, or 30 mW/cm^2 at ambient temperatures of 20° C or 25° C. Embryopathic effects at these levels of irradiation are highly dependent upon the ambient temperature in the chamber during the 6 hours of daily exposure.

Pregnant albino guinea pigs were exposed on days 18 through 25 of gestation for 60 minutes to 2450-MHz CW microwave radiation at a power density of 47 mW/cm^2. Caesarean sections followed by teratogenic examinations were performed on day 60 of gestation. Statistical analysis indicated that the microwave exposed litters had lower average brain mass and that the female conceptuses had lower average body mass.

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ABSTRACT

Pregnant CF-1 mice were exposed to 2450-MHz CW microwave irradiation at power densities of 0, 10, or 30 mW/cm^2 for 6 hours daily from gestational day 1 through day 18. All exposures occurred in an anechoic chamber maintained at 50% relative humidity with air temperature of 22° C. A group of pregnant colony cage control mice was maintained for each of the three exposure groups. Teratogenic examinations were performed on day 18 following Caesarean section of the maternal subject. Every third fetus was stained with alazarin red and examined for skeletal abnormalities. No significant differences between the groups were observed for fetal body mass, fetal brain mass, resorption, live fetuses, gross abnormalities, or skeletal abnormalities.

Subsequent experiments were performed on pregnant CF-1 mice at 0, or 30 mW/cm^2 at ambient temperatures of 20° C or 25° C. Statistical analysis revealed that embryopathic effects at these levels of irradiation are highly dependent upon the ambient temperature in the chamber during the 6 hours of daily exposure.

Pregnant albino guinea pigs were exposed on days 18 through 25 of gestation for 60 minutes to 2450-MHz CW microwave radiation at a power density determined to be 47 mW/cm^2. Caesarean sections were performed on day 60 of gestation and the conceptuses were examined for any sign of embryopathic or teratogenic damage. Statistical analysis indicated that the microwave exposed litters had lower average brain mass and that the female conceptuses had lower average body mass when compared to the sham exposed.

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LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATION	
C	-- Centigrade
CW	-- Continuous Wave
MHz	-- Megahertz
mW/cm^2	-- milliwatts per centimeter squared
SAR	-- Specific Absorption Rate
W/kg	-- Watts per kilogram

INTRODUCTION

At the beginning of this project, all of the research that had been reported with respect to the potential teratogenisis of microwave radiation had been accomplished at relatively high power levels (most in excess of 10 mW/cm^2). Also, the majority of the reports were from investigations using acute exposure conditions with durations of minutes or a few hours on a single day. In fact, few studies had exposure durations that extended beyond a single hour. A study by Berman, et al. (1978) reported on daily 100 minute exposures of CD-1 mice to 2450-MHz CW microwave radiation at several power densities. The different power densities were 0, 3.4, 14, and 28 mW/cm^2 with corresponding specific absorption rates (SAR) of 0, 2.0, 8.1, and 22 W/kg. At the end of the exposure at the highest level the average rectal temperature of the maternal subjects was 38.2 °C. The results of the study indicated a 10% decline in fetal body mass but no specific anomolies were observed in the fetuses at any one of the power densities, not even the highest. The analysis of variance did not identify the level of treatment exposure as a significant factor. However, when the number of exencephalic fetuses were pooled across all four of the power densities, there was a significant difference between the total number of microwave exposed and the sham exposed groups with most of the anomalous observations occurring at the highest exposure level.

Prior to beginning this investigation the studies available in the literature were reviewed and two rather broad generalizations regarding the teratogenic effects of microwave exposure appeared to emerge (O'Connor, 1980). First, the only consistent finding was reduced average fetal body mass in microwave exposed fetuses. One study by Berman et al., (1980) extended the measurement of fetal body mass seven days past the day of parturition. In that study the fetal body mass reduction persisted to the seventh day measurement.

Such functional deviations as reduced fetal body mass can be considered mild in comparison to fetal death or the appearance of gross structural abnormalities. The second generalization regarding the teratogenic effects of exposure to microwave radiation was that even these relatively mild functional deviations only were observed at high levels of exposure that clearly elevated the core temperature of the maternal organism. In fact, the hypothesis originally put forward by Chernovetz et al., (1975) suggested that only conditions that were just below thermal lethality for the maternal subject would produce these deviations. She provided support for this hypothesis from observations across three species of mice and rat (see O'Connor, 1980). Berman et al., (1981) also added support to this observation and Lary et al., (1979, 1980, 1982) and Lacy et al., (1980a, 1980b) systematically investigated the thermal parameters associated with the observation of reduced fetal body mass and the incidence of resorptions and abnormalities. From these studies it would appear that both the rate of temperature increase and the temporal duration over which the maternal organism must endure this high temperature are important variables in the production of teratogenic effects. In both the Chernovetz et al., (1975, 1977, 1979) and the Berman et al., (1978, 1980, 1981) studies, the duration of the exposure period was held constant and occasionally a core temperature elevation in the maternal subjects would result in the death of the orga-

nism. They concluded that it was necessary to raise maternal temperature to nearly lethal levels before resorptions, abnormalities, or alterations of fetal body mass were significantly increased or reduced.

Lary et al., (1979, 1980, 1982) and Lacy et al., (198-a, 1980b) varied the duration of the exposure in order to determine the threshold in maternal temperature elevation that would produce teratogenic effects. Since the exposures were terminated at specific sub-lethal temperatures, none of the maternal subjects actually died. These studies were conducted at 915 MHz as compared to the 2450-MHz frequency employed by most other investigators. The maternal temperature required to induce effects was reported to be 40°C. Maternal core temperatures following exposure in the Chernovetz and Berman studies for animals for whom reduced fetal body mass, resorptions, or anomalous conceptuses were reported were approximately 40-42°C. The temperature threshold determined by the Lary group does seem to be just below the lethal threshold for the maternal subjects.

At the time of the initiation of this investigation, the data on the teratogenic effects of microwave radiation had been obtained nearly exclusively from a single acute exposure to 2450-MHz CW radiation at power densities well above 10 mW/cm^2. When lower, but also acute exposures, were investigated (Chernovetz et al., 1977, 1979) no teratogenic effects were reported.

Typical laboratory exposure conditions do not resemble the exposure conditions found in the general environment. However, it is this condition that is of the most concern with regard to the exposure of the general population. In the general population, exposures are for long periods of time (from days to a lifetime) to what would be considered extremely low levels in comparison to the intensities used in the laboratory.

The purpose of the studies conducted for this contract was to obtain information with respect to relatively long-term, low-level exposure at 2450-MHz CW. The CF-1 laboratory mouse was chosen as the subject for the study to facilitate generalization and comparison with earlier reports. This same rationale guided the selection of 2450-MHz CW plane wave radiation. The initial work plan for the investigation called for exposures of CF-1 mice at five different power densities: 0, 0.1, 1.0, 10.0, and 30.0 mW/cm^2. This final report actually presents results from exposure of mice at the 0, 10.0, and 30.0 mW/cm^2 levels along with several additional studies performed following modification of the original contract work plan. The original plan was modified following statistical analysis of some of the 0, 10, and 30 mW/cm^2 exposure groups. An ambient temperature control study was added in which the 0 and 30 mW/cm^2 exposures were repeated at ambient temperatures of both 20°C and 25°C.

Following another modification, the study was expanded to investigate a larger mammal, the guinea pig. The guinea pig was chosen because of size and because much of the data on the teratogenic effects resulting from hyperthermia induced by non-microwave sources derived from studies conducted using the guinea pig. One of the conclusions from these non-microwave, hyperthermic studies was that the guinea pig tended to respond to hyperthermia with the production of specific abnormalities. Guinea pig fetuses exposed to hyperthermia had higher incidences of structural anomalies. Hyperthermia studies using the mouse or rat tended to report reduced average fetal body mass and increases in resorbed fetal material rather than specific structural

defects such as missing or deformed limbs, exencephaly, or eye and palate malformations. The effects in the guinea pig also were reported to occur at lower maternal core temperatures than those in either the mouse or the rat. The investigators for much of this hyperthermia data refer to the guinea pig as a more susceptible species with regard to thermally induced teratogenesis (Edwards and Wanner, 1977).

The hyperthermia studies provided a model for the design of the microwave investigations on the guinea pig. The post-exposure temperature of the maternal subject associated with the observation of deleterious effects from hyperthermia was 41°C. The initial microwave study attempted with the guinea pig resulted in average maternal core temperatures just below this 41°C level and did not produce any observable defects in the conceptuses. Since the average maternal temperature did not actually reach the same level as was reported to induce effects from non-microwave induced hyperthermia the study was repeated at a higher power density that resulted in some lethality to the maternal subjects.

To summarize, the contracted investigation was conducted to further delineate whether low-level, long-term exposures of CF-1 mice and guinea pigs to 2450-MHz CW microwave radiation would be embryopathic or teratogenic.

CONCLUSIONS

The studies did not result in observations of embryopathic or teratogenic effects in the CF-1 mouse exposed to 0, 10, or 30 mW/cm^2 microwave radiation at a frequency of 2450-MHz CW endured for 6 hours daily throughout 18 days of the gestation period. The 0 mW/cm^2 (sham) subjects had the lowest average fetal body mass and fetal brain mass. During the studies the temperature in the anechoic chamber was maintained at 22°C which is a common temperature at which microwave investigations have been reported. This relatively low temperature is used to counteract the heating effect of the microwave that would induce core temperature increases. In the present investigation, the sham animals were in the anechoic chamber for 6 hours daily for 18 days rather than a few minutes or hours on a single day and such a condition could induce mild cold stress.

In the second series of studies power densities of 0 and 30 mW/cm^2 were employed but at ambient temperatures in the anechoic chamber of 20°C and 25°C. When all of the exposure conditions were compared to one another and to the colony cage control subjects, it appeared that the sham animals in the 20°C and 22°C did experience mild cold stress. At an ambient temperature of 25°C the 30 mW/cm^2 exposed subjects exhibited lower fetal body mass and fetal brain mass as well as an increase in the number of abnormalities. At the cooler temperatures the 0 mW/cm^2 subjects were the lowest in mass, but the differences were not significant. The ambient temperature and its interaction with the microwave power level was the key to the appearance of decreases in fetal body mass and fetal brain mass. This supports an essentially thermal model for accounting for embryopathic and teratogenic effects following microwave exposure.

This result underscores the need for careful interpretation of data when the purpose of the interpretation is to help assess potential hazards to human beings. Many previous studies compare only a microwave exposure condition and a sham exposure condition. The main problem posed by such studies is that they lack ecological validity. It is all too easy to attribute observed effects to negative consequences of microwave exposure thus using the sham condition as if it is a representation of the normal condition without microwave treatment. The sham condition is indeed an important baseline and an important control, but it clearly is not an appropriate baseline to represent the normal environment for a species. The normal baseline would be one obtained in the actual environment and would represent the actual expected occurrence of deviations. Most animal studies use laboratory and not wild strains, but in such experiments, the colony cage control subjects present a better normal baseline with regard to the normal occurrence of teratogenisis for that laboratory strain.

The results of the present study could be interpreted as a comparison of mild heat stress with mild cold stress rather than sham and microwave (i.e. heated) exposed animals. At least in the present investigation, the mild cold stress condition was associated with reductions in body and brain mass in the fetuses. It is possible that the low-level of microwave induced heat or energy may be overriding the adverse experimental procedures that were introduced for the purpose of maintaining a normal body temperature in the microwave exposure condition.

The conclusion with respect to the guinea pig exposure is not clear. The female fetuses did have lower average fetal body mass in the microwave exposed condition than in the sham exposure or the colony cage control con-

dition. Also, overall fetal body mass as well as fetal brain mass differed significantly across groups if individual fetal data was used as the endpoint for analysis rather than the litter mean. No statistically significant differences in the incidence of abnormalities were observed, but all of the abnormal fetuses observed in the entire study were in the microwave exposure group. In the manner in which Edwards (1977) defines susceptibility, the guinea pig does not appear to be any more susceptible to this form of radiation than either the mouse or the rat, at least not with respect to the parameters used in this investigation.

RECOMMENDATIONS

The results of the study lead to questions regarding the interpretation of existing teratogenic data and its use in generalizing and extrapolating with regard to human hazard or risk in the general environment. Some of the results of the present investigation could be used to argue for differences between the microwave and sham exposure groups in fetal body mass if the statistical analysis excluded the colony or cage control subjects. Such an analysis would show a significant reduction in fetal body mass for our sham subjects, which without the colony control data might be interpreted as an increase in fetal body mass as a result of microwave exposure. This type of analysis would disregard the fact that the microwave exposed subjects had average fetal body masses that were nearly identical to what was observed in the colony cage control animals. Several summary reports routinely ignore colony cage control data even when it is given by the authors (Heynick and Polson, 1984). The presumption or assumption that sham conditions represent the normal environment without radiation could lead to erroneous interpretations of potential hazard to the general public. The effects observed following microwave exposure may, in fact, be the same as would be observed in the general population without any kind of exposure. Data that does not contain some reference to colony cage control baseline information is of limited value and must be used with caution in the assessment of standards intended for the general population. In future studies an additional group of animals should be included that are maintained in an anechoic chamber for the same length of time as the microwave exposed and sham exposed groups but at a temperature that matches, not the microwave ambient temperature condition, but the temperature in the cages of the colony control animals.

MATERIALS AND METHODS

Microwave Exposure Facility

The first phase of the project involved the fabrication and construction of the anechoic chamber, the microwave power source, and the temperature and humidity control unit.

The system arrangement is shown in Figure 1. The figure depicts a schematic of a cross sectional view of the exposure system showing the anechoic chamber, the microwave exposure system, and the air conditioning and humidity system. The microwave exposure area is enclosed in an anechoic chamber measuring 3.0 x 3.0 x 2.4 meter. The anechoic chamber is a Lindgren 4-Shield radio-frequency shielded room. The interior of the shielded room is rendered microwave anechoic by the absorber material lining. The walls and floor perimeter are lined with CVCB-9 absorber material while the ceiling and door are covered with AN-77 absorber material. The central floor area in the direct illumination region is covered with high performance VHP-26 pyramidal absorber. All of the absorber materials are Emerson and Cuming commercial products. The Lindgren anechoic chamber was purchased as surplus from LaBarge Electronics, a former private company in Tulsa, OK. Unless otherwise indicated all equipment was purchased direct from the manufacture.

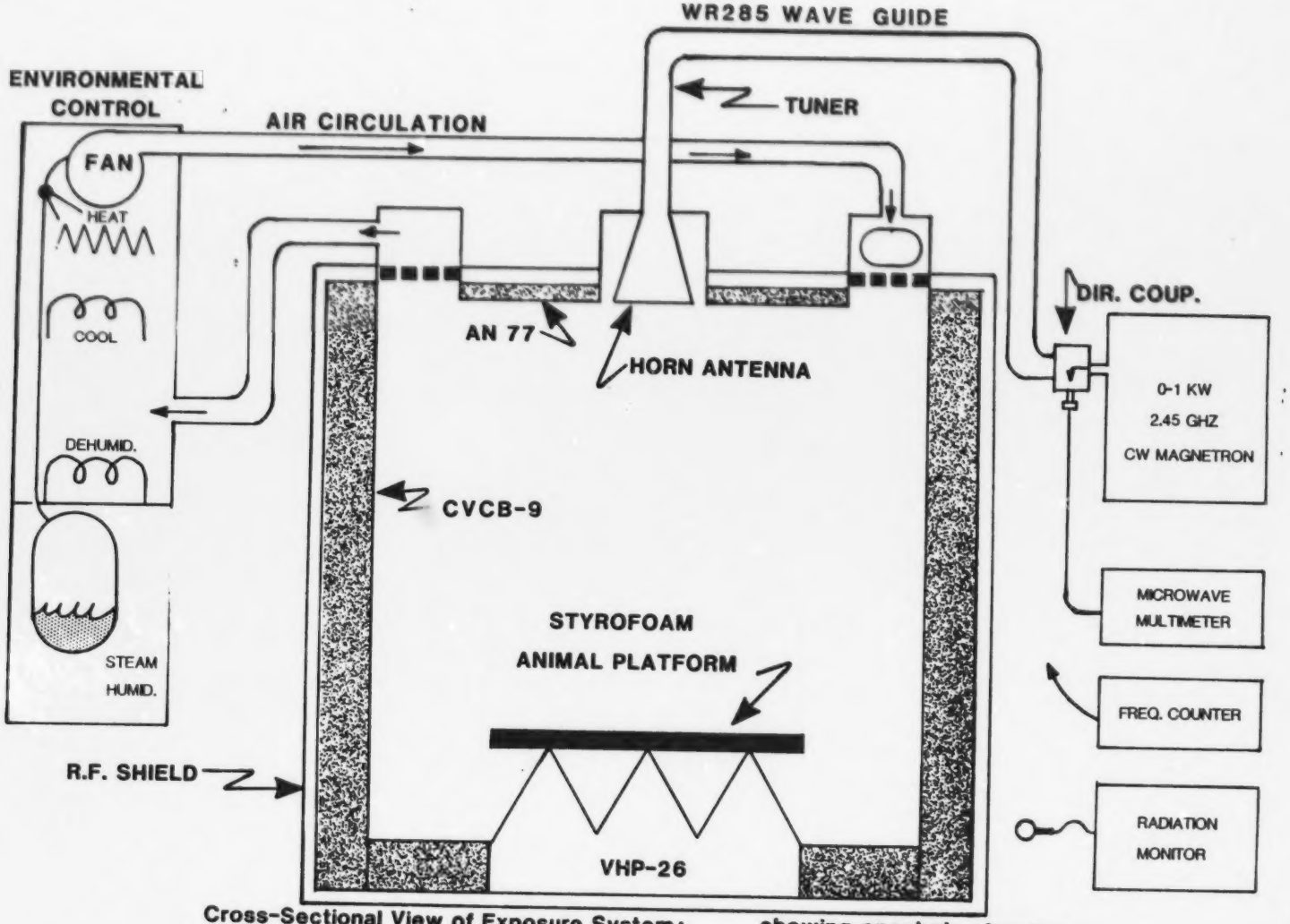
Microwave Power Source and System

The horn antenna is mounted on the ceiling and is a modified Narda 644 horn antenna. The antenna has been shortened to broaden the beam width of the antenna radiation pattern. A Narda 8601 Radiation Monitor with an 8621 omnidirection probe are used to measure field uniformity. Power densities uniform to 1.0 dB maximum variation are produced over an area of 1.0 square meter.

The Cober S1/V-F microwave power source provides continuous wave 2.45-GHz power at levels from 100 to slightly over 1000 watts. The power ripple is less than 50 watts peak to peak. The microwave output is coupled to the chamber through a directional coupler and WR-285 waveguide. A Narda 7000A microwave multimeter is used as a power meter to monitor and set the output power and as a reflectometer to measure antenna mismatch. A Racal-Dana 9921 microwave counter is used to verify the operating frequency. The waveguide runs to the antenna mounted on the top of the shielded enclosure. A Wavetek 2002 signal generator and the microwave multimeter are used to adjust the slide-screen tuner at the antenna feed point.

Animal Containers and Exposure Materials

A bilayer styrofoam platform was placed on top of the high performance VHP-26 pyramidal absorber. The two layers of styrofoam were separated by an air space. The top section of styrofoam had 18 holes placed equidistant on the surface to allow each animal container to be placed in a 23 x 23 cm area. The mouse exposure containers were Sweetheart brand plastic containers measuring



Cross-Sectional View of Exposure System: showing anechoic chamber, microwave plane wave illumination system, and air conditioning and humidity system.

4-1/2" diameter and 3" deep perforated with holes for ventilation. Each container had approximately 36 holes, each hole 3/16" in diameter.

For the guinea pig exposures, a single layer of styrofoam was placed on top of the VHP-26 pyramidal absorber. The pigs were exposed in plexiglas cylindrical cages measuring 5" in diameter and 7-1/4" in length. These cages were also perforated with 36 holes of 3/8" diameter for ventilation and air flow. The cylinders rested on a plexiglas support, one end of which was removable for easy placement of the animals in the container. This support placed the cylinder in which the animal was located 1-1/4" above the styrofoam platform.

Temperature and Humidity Control

A Vista Scientific Environ-Aire E-1000 unit controlled the temperature and relative humidity. Temperature ranges from 10°C to 30°C at 50% relative humidity are specified. Throughout the investigations, the humidity control performed erratically.

EXPERIMENTAL PROCEDURES

Four separate studies were conducted. All experiments were performed at a frequency of 2450-MHz CW microwave radiation in the anechoic chamber described in the section entitled "Materials and Methods."

Experiment One

In this study the four exposure conditions consisted of power densities of 0, 10, or 30 mW/cm^2 with concurrent cage control colony subjects maintained during the exposure period for each group.

Subjects: The subjects for this study were sperm positive CF-1 mice bred in the laboratory at the University of Tulsa. Original stock for the colony was obtained from Charles Rivers Breeding Laboratory. The animal vivarium was maintained at 70°F with relative humidity of 60-75%. A 12/12 hour light/dark cycle (0800 to 2000) was maintained automatically. The animals were caged in clear plastic containers with wire tops. The floors of the containers were covered with wood chips. For breeding, males were placed in a cage with five to six females averaging 80 days of age. Male breeders began at approximately 42 days of age and the mean age for the males was 210 days. Each morning the females were checked for sperm plugs and the presence of a sperm plug was counted as day 1 of the gestation period. At this time the female was assigned randomly to either the current exposure or cage control condition. From day 1 of gestation the female was placed in a large group cage (30 x 38 x 17.5 cm) with other sperm positive mice in the same treatment group. Laboratory rodent chow and tap water was available ad libitum in the animal vivarium.

Procedure: The 30, 10, and 0 mW/cm^2 exposure groups were run sequentially. A colony cage control group was maintained for each of the three exposure conditions. After the identification of a sperm plug and on each of the subsequent 17 days each female was removed from the group cage, assessed for body mass, placed in the plastic container described above, transported to the anechoic chamber located in an adjoining room, and placed in one of the 18 available positions on the styrofoam platform in the chamber. The position of each mouse in the anechoic chamber was rotated daily so that by the end of the 18 day exposure period, each mouse had occupied each available position for one day of exposure. The subjects were exposed for 18 consecutive days for 6 hours beginning at 0900h and ending at 1500h. Male, nonbreeder mice of the same strain were used for fillers if 18 sperm positive females were not available on a given day. Each of the exposure conditions was continued until 25 gravid mice had been confirmed by Caesarean section. The ambient temperature in the chamber was maintained at 22°C and the relative humidity was set for 50%. The average relative humidity was 62% in this experiment.

Following the exposure on day 18, the maternal subjects were euthanized by cervical dislocation. Caesarean sections were performed by making longitudinal abdominal incisions that exposed the uterine horns. The number and placement of resorptions and visible fetuses was noted and the

conceptuses were removed. The fetuses were sexed, viability was noted, and they were examined for the presence of any gross structural abnormality including cleft palate. Body mass was assessed on a Mettler PC440 top-loading balance. The fetal brain was removed, placed in a weigh boat and assessed for mass. Every third fetus was placed in KOH for later staining with Alizarin red to observe skeletal structure. After staining, the fetuses were stored in glycerin and examined under a light microscope for the number of sternal ossifications and number of ribs. At this time any other observable skeletal abnormality also was noted.

Experiment Two

Experiment Two was conducted using CF-1 mice and the same breeding and exposure procedures as Experiment One, with the exception that the anechoic chamber was maintained at either 20°C or 25°C and only two exposure levels were compared: 0 and 30 mW/cm^2. The conditions were run sequentially and colony cage control animals were maintained for each of the exposure groups. Caesarean sections, fetal observations, and staining procedures were performed as for Experiment One.

Experiment Three

The subjects, breeding, and exposure procedures were identical to those for Experiments One and Two, with the exception that the animals were exposed for only 100 minutes to either 0 or 30 mW/cm^2 with the temperature of the anechoic chamber again maintained at 22°C. Colony cage control animals were maintained for both exposure periods. Caesarean sections, fetal observations and staining procedures were the same as outlined for the earlier experiments.

Experiment Four

Subjects: The subjects for this study were Hartley (HA)BR guinea pigs obtained from Charles Rivers Laboratories. The females were housed in groups of four in a plastic cage measuring 55 x 33 x 20 cm. Males were housed singly. Breeding began when the females were 55 to 78 days of age and the males were 61 to 77 days of age. The light-dark cycle in the vivarium was maintained automatically as a 12/12 light/dark (0800 - 2000h) cycle. The temperature in the vivarium was 72°F and the relative humidity was maintained at 50%. Guinea Pig Maintenance Diet and tap water was available ad libitum in the colony.

For breeding, the females were placed singly in the male's cage. Estrus for the females was determined by checking the vaginal opening each day until the membrane covering had receded. The female then was placed with the male and checked daily for the presence of a sperm plug. The day a plug was observed was marked as day 1 of gestation. At this time the animal was assigned randomly to either the colony cage control group or the current (0 or 47 mW/cm^2) exposure condition.

Procedure: Once a sperm plug had been detected the females were left in their own home cages and handled only for routine cage maintenance

through day 17 of gestation. The exposure occured from day 18 through day 25 of gestation. The animals were assessed for body mass, placed in the plastic cylindrical exposure containers, transported to the anechoic chamber located in the adjoining room, and exposed for 60 minutes. Four animals were exposed at one time and non-breeding males were used as fillers when necessary. The position of the animal in the anechoic chamber was rotated daily. The temperature in the anechoic chamber was maintained at 22°C and the relative humidity was maintained at 50%. The animals were placed 46 inches below the horn antenna and the power density at this location later was determined to be 47 mW/cm^2. This location was chosen because it resulted in maternal post-exposure core temperatures of 41°C after 60 minutes. The 0 or the 47 mW/cm^2 exposures occurred during the same two hour period each day (1500h to 1700h) and the two conditions were rotated so that on one day the 0 mW/cm^2 group was exposed during the first hour and on the subsequent day the 47 mW/cm^2 group was exposed during the first hour. Both pre- and post-exposure core temperatures were taken with a Bailey BAT8C thermometer using a RET-3 rectal probe. From day 26 until day 60 of gestation, the animals remained in their home cages and were handled only for routine cage maintenance.

On day 60 the females from all three groups were sacrificed by inhalation of chloroform fumes. Caesarean sections were performed by making a ventral longitudinal incision that exposed the left and right horns of the uterus. The position of resorptions and viable conceptuses was noted prior to their removal from the uterus. All fetuses were sexed, assessed for body mass, and crown-to-rump length was measured. The fetuses were also examined for any observable structural abnormality including cleft palate. The fetal brain was then removed, placed in a weigh boat, and assessed for mass.

RESULTS AND DISCUSSION

All of the data from this investigation was analysed using analysis of variance available in statistical packages from SPSS and BMD. All analyses, including those pertaining to microwave exposure parameters, were performed only on data obtained for females that proved to be gravid following the Caesarean section. For each experiment, the initial analysis was a one way analysis of variance for each endpoint. Duncan's multiple range tests were used to determine differences between individual groups.

For clarity we have separated the data into tables that reflect either measurements that were obtained on the maternal subjects during the exposure phase or measurements that were obtained from the conceptuses following Caesarean section and removal from the uterus. A list of the pertinent analyses that were performed on both the maternal subjects and the conceptuses is presented in the Appendix along with the F values, degrees of freedom, and probability values associated with each analysis. In discussing the results of the study, only significant results will be presented in text. Some variables that were of major importance to the study such as mean fetal body mass will be presented regardless of statistical significance.

Experiment One

As can be observed in Table 1, a total of 114 gravid dams were used in the analyses for the CF-1 mouse. After determining that none of the colony cage control groups differed significantly on any of the variables of interest, a random sample of 27 colony cage control litters was used in the one way analysis of variance.

Table 1. AVERAGES ASSOCIATED WITH MATERNAL SUBJECTS
MEAN (S.E.)

	CAGE CONTROL	SHAM CONTROL	10 mW/cm2	30 mW/cm2	TOTAL
Number of Gravid Dams	27	26	25	36	114
Number of Treated Non-Gravid Mice/ Total Number of Mice	52/178	15/41	10/35	28/64	95/318
Age at Caesarean Section	101.93 (4.10) a	114.35 (4.26) a,b,c,	93.52 (2.57) c	96.17 (4.21) b	101.10 (2.10)
Dam Mass on First Day of Pregnancy	28.10 (0.46)	30.26 (0.52) a	30.03 (0.37) b	27.91 (0.46) a,b	29.17 (0.25)

(continued)

Table 1. AVERAGES ASSOCIATED WITH MATERNAL SUBJECTS
MEAN (S.E.)

	CAGE CONTROL	SHAM CONTROL	10 mW/cm2	30 mW/cm2	TOTAL
Dam Mass on Day of Caesarean Section	51.62 (0.80) b	49.52 (1.16) a	52.08 (0.79) c	46.63 (0.87) a,b,c	49.67 (0.50)
Weight Gain	22.62 (0.63) b,d	19.26 (0.80) c,d	22.06 (0.57) a,c	18.71 (0.70) a,b	20.50 (0.38)
Implants	12.52 (0.36)	12.27 (0.58)	13.12 (0.28) a	11.58 (0.40) a	12.30 (0.21)
Microwave Exposure In mW/cm2	____	____	9.96 (0.02)	27.65 (0.03)	____
Time In Chamber In Minutes	____	356.36 (0.91) a	361.74 (0.31) a	358.08 (0.41) a	358.62 (0.40)
Ambient Temperature in Chamber	____	21.29 (0.02)	21.95 (0.06)	23.78 (1.25)	22.51 (0.53)
Humidity in Chamber	____	63.44 (0.19) a	62.80 (0.16)	59.67 (1.56) a	61.70 (0.67)

Within a row, cells with the same subscripts are significantly different from one another.

Although the age of the maternal subject at the time of Caesarean section differed across the groups ($F = 5.063$; $df = 3, 110$; $p = .003$) the actual difference between the youngest females (10 mW/cm^2) and the oldest females (0 mW/cm^2) was eleven days. The mass of the dam on the first day of gestation differed across the conditions ($F = 5.82$, $df = 3, 110$; $p = .001$) with the difference between the heaviest group (0 mW/cm^2) and the lightest group (30 mW/cm^2) being two grams. The mass of the dam on the day of Caesarean section also differed ($F = 8.02$; $df = 3, 110$; $p = 0001$) with the difference between the two most extreme groups being five grams. Mass

gained during the exposure period was also different ($F = 8.20$; df = 3, 110; $p = 0001$) with a total range from the lowest to the highest of four grams. The number of implants per litter approached significance ($F = 2.39$; df = 3, 110; $p = .072$). The microwave power density to which the subjects were exposed differed according to experimental design. The amount of time the groups actually were in the anechoic chamber was different ($F = 20.15$; df = 2, 84; $p = .0001$) with the maximum difference between groups being six minutes. The ambient temperature in the chamber was not different but there was a difference in the humidity in the chamber ($F = 3.47$; df = 2, 84; $p = .036$).

The averages of the measurements associated with the conceptuses are presented in Table 2. No differences in average litter fetal body mass or average litter fetal brain mass were observed. A difference was observed in the number of live fetuses ($F = 2.18$; df = 3, 110; $p = .095$) with the 10 mW/cm^2 group having more than the 30 mW/cm^2 group. An analysis of covariance on mean fetal body mass with number of live fetuses as the covariate was non-significant ($F = 1.17$; df = 3, 109; $p = 0.327$). No difference were observed in the average number of still born, resorbed, or abnormal fetuses.

Table 2. AVERAGES ASSOCIATED WITH CONCEPTUSES
LITTER MEANS (S.E.)

	CAGE CONTROL	SHAM CONTROL	10 mW/cm2	30 mW/cm2	TOTAL
Number of Litters	27	26	25	36	114
Fetal Body Mass	1.07 (0.01)	1.03 (0.03)	1.04 (0.02)	1.05 (0.02)	1.05 (0.01)
Fetal Brain Mass	0.064 (0.002)	0.062 (0.002)	0.063 (0.001)	0.065 (0.001)	0.064 (0.001)
Number of Live Males	5.70 (0.41)	4.65 (0.44)	5.96 (0.47)	5.19 (0.29)	5.36 (0.20)
Number of Live Fetuses	11.37 (0.47)	10.88 (0.61)	12.32 (0.38) a	10.75 (0.42) a	11.27 (0.24)
Number of Dead Fetuses	0.07 (0.05)	0.04 (0.04)	0.00 (0.00)	0.08 (0.08)	0.05 (0.03)
Number of Resorbed Fetuses	1.07 (0.23)	1.35 (0.27)	0.80 (0.22)	0.75 (0.21)	0.97 (0.12)

(continued)

Table 2. AVERAGES ASSOCIATED WITH CONCEPTUSES
LITTER MEANS (S.E.)

	CAGE CONTROL	SHAM CONTROL	10 mW/cm2	30 mW/cm2	TOTAL
Number of Abnormal Fetuses	0.30 (0.12)	0.62 (0.25)	0.36 (0.13)	0.50 (0.16)	0.45 (0.08)
Number of Fetuses With 14 Ribs	0.74 (0.22)	0.54 (0.16)	0.28 (0.12) a	1.06 (0.19) a	0.69 (0.09)
Sternal Ossifications > 6 <	0.18 (0.08)	0.31 (0.12)	0.24 (0.10)	0.28 (0.10)	0.25 (0.05)
Other Skeletal Abnormalities	0.44 (0.16)	0.19 (0.08)	0.00 (0.00) a	0.58 (0.21) a	0.33 (0.08)

Within a row, cells sharing the same subscripts are significantly different from one another.

The 10 and 30 mW/cm^2 groups also differed in the average number of fetuses with 14 ribs ($F = 3.39$, df = 3, 110; $p = .021$) and the number of fetuses with other skeletal abnormalities ($F = 2.78$; df = 3, 110; $p = .044$).

Experiment Two

Table 3 presents the averages and the standard errors for the measurements taken on the maternal subjects exposed at an ambient temperature of 25°C.

Table 3. AVERAGES ASSOCIATED WITH EXPOSURE OF MATERNAL SUBJECTS
MEANS (S.E.)

	CAGE CONTROL	0 mW/cm2	30 mW/cm2	TOTALS
Number of Gravid Dams	28	23	19	70

(continued)

Table 3. AVERAGES ASSOCIATED WITH EXPOSURE OF MATERNAL SUBJECTS
MEANS (S.E.)

	CAGE CONTROL	0 mW/cm2	30 mW/cm2	TOTALS
Ambient Temperature	—	24.13 (0.03) a	25.11 (0.11) a	24.57 (0.09)
Relative Humidity in Chamber	—	52.66 (0.77) a	44.79 (0.54) a	49.10 (0.78)
Time in Chamber in Minutes	—	361.77 (0.18) a	355.68 (0.87) a	359.02 (0.62)
Dam Mass on Day 1 of Gestation	30.39 (0.58) a	31.23 (0.52) b	27.71 (0.76) a,b	29.94 (0.39)
Dam Mass on Day of Caesarean Section	53.20 (1.15) a	51.58 (1.12) b	43.52 (0.91) a,b	50.04 (0.81)
Dam Mass Gain During Gestation	22.81 (0.86) a	20.34 (0.90) a	15.81 (0.62) a	20.10 (0.59)
Age of Dam at Caesarean Section	98.14 (3.26) a	108.35 (1.69) a	76.89 (3.59) a	95.73 (2.25)
Age of Male at Time of Breeding	130.79 (12.32) a	170.87 (19.48)	193.16 (12.17) a	160.89 (9.15)
Number of Implants	12.29 (0.47)	12.35 (0.56)	11.53 (0.56)	12.10 (0.30)

Within a row, cells with same subscripts are significantly different from one another.

These analyses were performed on the 70 gravid dams that were final subjects in this study and their conceptuses (as presented in Table 4).

Table 4. AVERAGES ASSOCIATED WITH CONCEPTUSES
LITTER MEANS (SE)

	CAGE CONTROL	0 mW/cm2	30 mW/cm2	TOTALS
Number of Litters	28	23	19	70
Fetal Mass	1.12 (0.03) a	1.07 (0.03) b	0.93 (0.02) a,b	1.05 (0.02)
Fetal Brain Mass	0.063 (0.002)	0.064 (0.001) a	0.059 (0.002) a	0.062 (0.001)
Number of Live Fetuses	11.29 (0.43)	10.74 (0.67)	9.95 (0.55)	10.74 (0.32)
Number of Live Males	5.36 (0.30)	5.48 (0.41)	5.21 (0.51)	5.36 (0.22)
Number of Dead Fetuses	0.00 (0.00)	0.04 (0.04)	0.05 (0.05)	0.03 (0.02)
Number of Resorbed Fetuses	1.00 (0.22)	1.57 (0.39)	1.53 (0.42)	1.33 (0.19)
Number of Abnormal Fetuses	0.14 (0.07) a	0.17 (0.10)	0.53 (0.21) a	0.26 (0.07)
Number of Fetuses With 14 Ribs	0.29 (0.13)	0.30 (0.12)	0.58 (0.27)	0.37 (0.10)
Sternal Ossifications > 6 <	0.21 (0.15)	0.30 (0.12)	0.63 (0.30)	0.36 (0.11)

(continued)

Table 4. AVERAGES ASSOCIATED WITH CONCEPTUSES
LITTER MEANS (S.E.)

	CAGE CONTROL	0 mW/cm2	30 mW/cm2	TOTALS
Number of Other Skeletal Abnormalities	0.04 (0.04)	0.09 (0.09)	0.00 (0.00)	0.04 (0.03)

Within a row, cells with same subscripts are significantly different from one another.

These groups did differ significantly with regard to the average litter fetal body mass ($F = 11.14$; $df = 2, 67$; $p = 0001$). Average litter fetal brain mass approached significance ($F = 2.74$; $df = 2, 67$; $p = .07$) as did the number of abnormal fetuses ($F = 2.71$; $df = 2, 67$; $p = .07$). Table 5 presents the averages and standard errors for measurements from 54 gravid dams and Table 6 presents averages for measurements on the conceptuses that were exposed to 0 or 30 mW/cm^2 with the ambient temperature maintained at 20°C. Averages for the colony cage control subjects are also given.

Table 5. AVERAGES ASSOCIATED WITH EXPOSURE OF MATERNAL SUBJECTS
LITTER MEANS (S.E.)

	CAGE CONTROL	0 mW/cm2	30 mW/cm2	TOTALS
Number of Gravid Dams	16	13	25	54
Ambient Temperature In Chamber	____	20.44 (0.08) a	18.95 (0.19) a	19.46 (0.17)
Relative Humidity in Chamber	____	51.24 (0.34) a	59.75 (1.02) a	56.83 (0.95)

(continued)

Table 5. AVERAGES ASSOCIATED WITH EXPOSURE OF MATERNAL SUBJECTS
MEANS (S.E.)

	CAGE CONTROL	0 mW/cm2	30 mW/cm2	TOTALS
Time In Chamber In Minutes	——	361.52 (0.88) a	363.42 (0.47) a	262.77 (0.45)
Dam Mass on Day 1 of Gestation	28.91 (0.77)	28.93 (0.65)	27.64 (0.57)	28.33 (0.38)
Dam Mass on Day of Caesarean Section	50.94 (1.56) a	8.41 (1.20)	45.78 (1.19) a	47.94 (0.82)
Dam Mass Gain During Gestation	22.03 (1.49) a	19.48 (1.23)	18.14 (0.83) a	9.62 (0.68)
Age of Dam at Caesarean Section	94.44 (3.26)	97.15 (4.44)	90.56 (2.45)	93.30 (1.83)
Age of Male at Time of Breeding	429.19 (172.06)	229.84 (16.91)	210.12 (18.43)	279.78 (52.42)
Number of Implants	11.69 (0.57)	11.15 (0.49)	11.00 (0.51)	11.24 (0.31)

Within a row, cells with same subscripts are significantly different from one another.

Table 6. AVERAGES ASSOCIATED WITH CONCEPTUSES
LITTER MEANS (S.E.)

	CAGE CONTROL	0 mW/cm2	30 mW/cm2	TOTALS
Number of Gravid Dams	16	13	25	54
Fetal Mass	1.05 (0.08)	1.07 (0.04)	1.08 (0.03)	1.07 (0.03)
Fetal Brain Mass	0.067 (0.005) a	0.134 (0.046) a,b	0.066 (0.002) b	0.083 (0.012)
Number of Live Fetuses	9.75 (0.92)	10.38 (0.64)	9.48 (0.52)	9.78 (0.39)
Number of Live Males	5.62 (0.71)	4.92 (0.52)	4.64 (0.45)	5.00 (0.32)
Number of Dead Fetuses	0	0	0	0
Number of Resorbed Fetuses	1.94 (0.61)	0.77 (0.32)	1.52 (0.27)	1.46 (0.24)

(continued)

Table 6. AVERAGES ASSOCIATED WITH CONCEPTUSES
LITTER MEANS (S.E.)

	CAGE CONTROL	0 mW/cm2	30 mW/cm2	TOTALS
Number of Abnormal Fetuses	0.25 (0.14)	0.54 (0.29)	0.44 (0.12)	0.41 (0.10)
Number of Fetuses With 14 Ribs	0.31 (0.18)	0.38 (0.21)	0.20 (0.10)	0.28 (0.09)
Sternal Ossifications > 6 <	0.19 (0.10)	0.54 (0.31)	0.12 (0.07)	0.24 (0.09)
Number of Other Skeletal Abnormalities	0.00 (0.00)	0.31 (0.24)	0.16 (0.11)	0.15 (0.08)

No significant differences in average litter fetal body mass were observed but there were significant differences in average litter fetal brain mass ($F = 3.35$; $df = 2, 51$, $p = .043$). No other significant differences were observed.

Experiment Three

Table 7 presents averages and standard errors for measurements taken on CF-1 mice exposed for 100 minutes to 0 or 30 mW/cm^2, as well as for their concurrent colony cage controls.

Table 7. AVERAGES FOR CF-1 MICE EXPOSED TO 2450 MHz CW FOR 100 MINUTES
MEANS (S.E.)

	CAGE CONTROL	0 mW/cm2	30 mW/cm2	TOTALS
Number of Gravid Dams	12	9	10	31
Dam Mass Gain During Gestation	24.79 (1.16) b	22.92 (0.69) a	17.66 (1.64) a,b	21.95 (0.89)
Number of Implants	11.42 (0.61)	12.00 (0.53)	9.60 (1.33)	11.00 (0.53)
Fetal Body Mass	1.08 (0.03)	1.07 (0.05)	1.09 (0.03)	1.08 (0.02)
Fetal Brain Mass	0.06 (0.001)	0.06 (0.002)	0.06 (0.001)	0.06 (0.001)
Number of Live Fetuses in Litter	10.25 (0.56) a	11.00 (0.71) b	7.50 (1.15) a,b	9.58 (0.53)
Number of Resorbed Fetuses in Litter	1.17 (0.30)	1.00 (0.23)	2.10 (0.62)	1.42 (0.25)

Within a row, cells with same subscripts are significantly different from one another.

A total of 31 gravid mice and their conceptuses were analyzed. Neither average fetal body mass nor average fetal brain mass were significantly different for the three groups. No differences were observed in the number of still born, resorbed, or abnormal fetuses.

Experiment Four

A total of 25 gravid guinea pigs survived the treatment conditions and the measurements from these dams and their conceptuses were analyzed using one way analysis of variance comparing the colony cage control subjects

with the sham exposed and microwave exposed subjects. The averages and the standard errors for this experiment are presented in Tables 8, 9, and 10. The pre-exposure temperatures of the sham and microwave exposed groups did not differ from one another. The post-exposure temperatures of sham exposed dams were significantly lower than those of the microwave exposed dams ($F > 100$) by 4.1°C and the post-exposure temperature for the microwave exposed animals was 3.06°C higher than their pre-exposure temperature.

Table 8. AVERAGES ASSOCIATED WITH MATERNAL SUBJECTS
MEAN (S.E.)

	CAGE CONTROL	SHAM EXPOSED	MICROWAVE EXPOSED	TOTALS
Number of Gravid Dams	7	8	10	25
Pre-Exposure Temperature of Dam	_____	37.85 (0.04)	37.96 (0.06)	_____
Post-Exposure Temperature of Dam	_____	36.93 (0.08)	41.02 (0.08)	_____
Number of Deaths	1-Day 60 3 Fetuses	0	1-Day 20 3 Fetuses 1-Day 22 0-Fetuses	3
Number of Premature Deliveries	0	1-Day 52 3 Fetuses	1-Day 49 4 Fetuses	2

One of the cage control animals died on day 60 of gestation and the autopsy revealed the presence of three fetuses. Two of the microwave exposure animals died, one on day 20 of gestation with 3 fetuses and the other on day 22 of gestation but this female was not gravid. Both microwave exposure deaths occurred during the days of exposure. Two animals delivered prematurely, one in the sham exposure condition delivered 3 fetuses on day 52 of gestation and one of the microwave exposed dams delivered 4 fetuses on day 49 of gestation.

The average maternal mass for the sham and microwave exposed groups across the eight days of treatment is presented in Figure 2. A repeated measures analysis of variance revealed a significant interaction between

condition and days of treatment (F = 6.57; df = 7,112; p = .0001) with the microwave exposed dams showing a consistent loss of mass across the days of exposure.

Analysis for the conceptuses were performed both on litter means (Table 9) and individual fetal data points (Table 10).

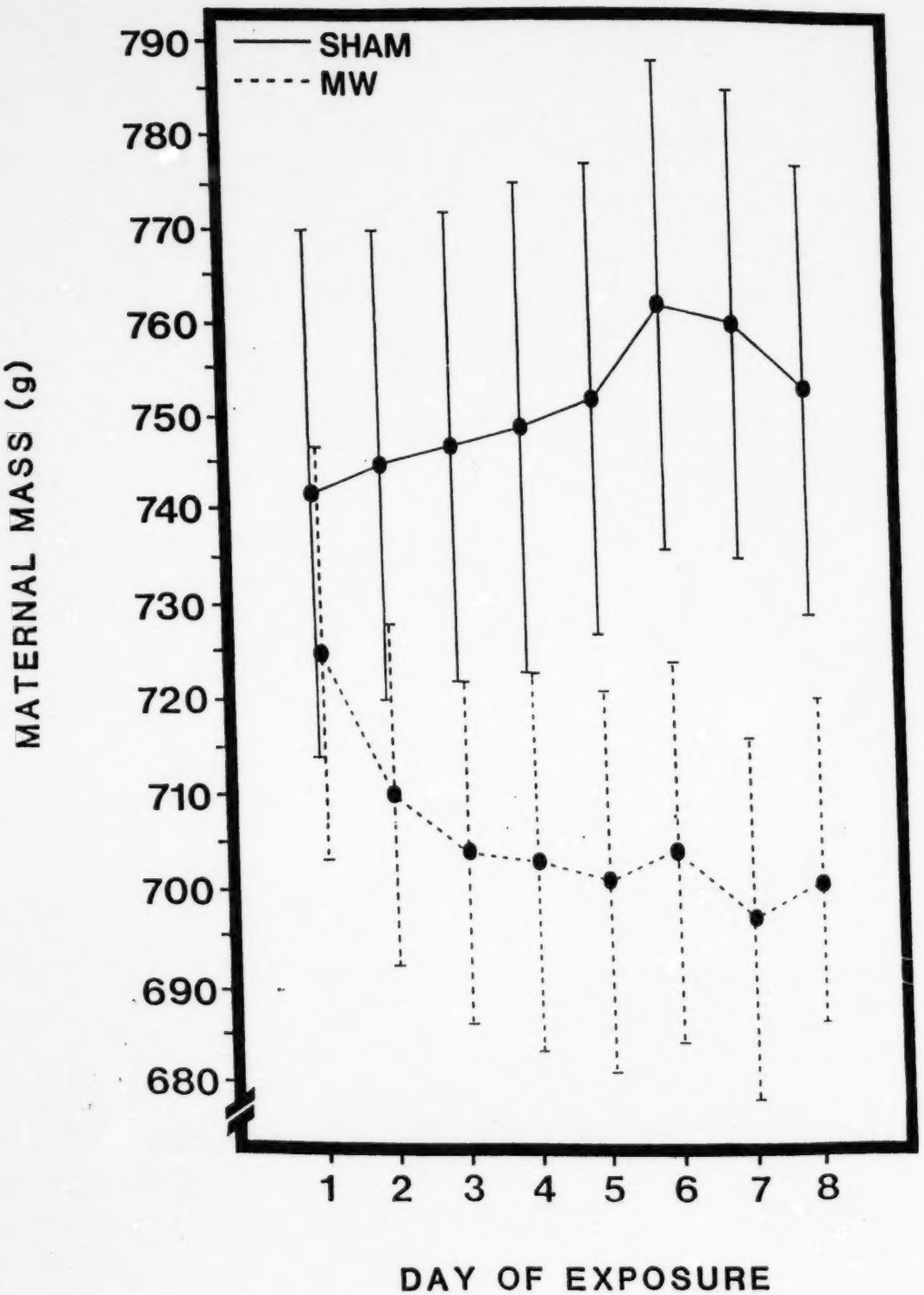
Table 9. AVERAGES ASSOCIATED WITH CONCEPTUSES
LITTER MEANS (S.E.)

	CAGE CONTROL	SHAM EXPOSED	MICROWAVE EXPOSED	TOTALS
Number of Litters	7	8	10	25
Number of Live Fetuses	2.86 (0.46)	3.13 (0.29)	2.50 (0.31)	2.80 (0.20)
Fetal Body Mass	64.74 (4.15) a	73.19 (1.25) a	67.36 (1.91)	68.49 (1.54)
Fetal Brain Mass	2.40 (0.07)	2.52 (0.02)	2.21 (0.09)	2.36 (0.05)
Fetal Crown-to-Rump	12.74 (0.28)	13.22 (0.15)	13.02 (0.17)	13.01 (0.12)
Number of Live Males	1.80 (0.58)	1.87 (0.40)	1.33 (0.23)	1.64 (0.21)
Male Body Mass	66.01 (5.94)	63.97 (6.19)	66.05 (3.60)	65.28 (2.87)
Number of Live Females	2.20 (0.37)	1.67 (0.21)	1.63 (0.26)	1.79 (0.16)
Female Body Mass	66.15 (2.51) a	75.54 (1.94) a,b	66.82 (2.14) b	69.39 (1.55)

Cells with the same subscripts are significantly different from one another.

The analyses on litter means showed significant differences for the female offspring with respect to fetal body mass (F = 5.37; df = 2, 16; p = .02). The females from dams exposed to microwave radiation were signi-

MATERNAL MASS FOR SHAM AND MICROWAVE EXPOSED GUINEA PIGS



ficantly lighter. When individual fetal data points were analyzed, differences in both average fetal body mass and average fetal brain mass emerged. The body mass of the fetuses was different ($F = 4.62$; $df = 2, 67$; $p = .01$) as was the fetal brain mass ($F = 14.86$; $df = 2, 67$; $p = .001$). The averages associated with the comparisons based on individual fetal means appear in Table 10.

Table 10. AVERAGES ASSOCIATED WITH CONCEPTUSES INDIVIDUAL MEANS (S.E.)

	CAGE CONTROL	SHAM EXPOSED	MICROWAVE EXPOSED	TOTALS
Number of Fetuses	20	25	25	70
Fetal Body Mass	67.31 (2.11) a	72.90 (1.33) a,b	66.54 (1.58) b	69.03 (1.00)
Fetal Brain Mass	2.44 (0.04) b	2.51 (0.03) a	2.23 (0.05) a,b	2.39 (0.03)
Fetal Crown-to-Rump Length	12.83 (0.18)	13.21 (0.11)	12.96 (0.13)	13.01 (0.08)

Cells with the same subscripts are significantly different from one another.

Discussion

The results of the investigation suggest that microwave radiation under these conditions of exposure does not produce embryopathic or teratogenic effects in either the CF-1 mouse or the Hartley guinea pig. Some differences were observed in fetal body and fetal brain mass in the guinea pig samples but they were primarily restricted to the female offspring.

Several significant differences associated with the maternal subjects in the study on the CF-1 mouse require comment. In the first experiment on the CF-1 mouse, several differences in maternal mass both on the initial day of gestation and at day 18 were observed. The numerical value of the differences is small and are not accompanied by significant differences in either the number of implants or smaller fetuses. The significant difference in the duration of exposure was also slight compared to the overall

time of exposure. Measurements taken every day across several months could be expected to vary by a few minutes if only with regard to technician speed in moving the subjects in and out of the chamber. A significant difference in live fetuses was observed but it was not supported by concurrent differences in the number of implants, resorbed, or still born fetuses.

Significant differences in average fetal body as well as average fetal brain mass did occur when the ambient temperature in the chamber was raised to 25°C, lending further support to the conclusion that the type of teratogenic effects observed following exposure to microwave radiation are thermally related or induced.

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ANALYSES PERFORMED ON CF-1 MOUSE DATA AT AN AMBIENT TEMPERATURE OF 22°C

ENDPOINT	F	df	p
Age of female at Caesarian section	5.063	3, 110	.0025
Dam Weight at first day of gestation	5.816	3, 110	.0010
Dam Weight on day of Caesarian	8.019	3, 110	.0001
Mean Litter Fetal Mass	0.820	3, 110	.4858
Mean Litter Fetal Brain Mass	0.816	3, 110	.4876
Number of Live Males in Litter	1.980	3, 110	.1212
Number of Live Fetuses in Litter	2.173	3, 110	.0953
Number of Dead Fetuses in Litter	0.383	3, 110	.7654
Number of Resorbed Fetuses in Litter	1.434	3, 110	.2367
Number of Abnormal Fetuses	0.706	3, 110	.5501
Number of Fetuses with 14 Ribs	3.394	3, 110	.0205
Number of Fetuses with Fewer or More than 6 sternal ossifications	0.250	3, 110	.8609
Skeletal Abnormalities Other than Ribs	2.783	3, 110	.0443
Age of Male at Breeding	0.420	3, 109	.7391
Time in Chamber in Minutes	20.149	2, 84	.0000
Ambient Temperature in Chamber	2.240	2, 84	.1128
Humidity in Chamber	3.467	2, 84	.0357
Weight Gain by Maternal Subjects	8.199	3, 110	.0001
Number of Implants	2.392	3, 110	.0724

ANALYSES PERFORMED ON GUINEA PIG DATA

ENDPOINT	F	df	p
Litter Size	0.875	2, 22	.4310
Mean Litter Body Mass	2.781	2, 22	.0838
Mean Litter Brain Mass	5.093	2, 22	.0152
Mean Crown to Rump Length	1.313	2, 21	.2902
Number of Males in Litter	0.684	2, 19	.5168
Number of Females in Litter	1.148	2, 16	.3420
Body Mass of Males in Litter	0.055	2, 19	.9470
Body Mass of Females in Litter	5.365	2, 16	.0165
Fetal Body Mass, Individual Pup	4.615	2, 67	.0132
Fetal Brain Mass, Individual Pup	4.615	2, 67	.0000
Crown Rump Length, Individual Pup	2.006	2, 66	.1426

PRESENTATIONS FROM CONTRACT

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GLOSSARY

ABSORPTION The irreversible conversion of electromagnetic energy into other forms of energy as a result of interaction with matter.

ANECHOIC CHAMBER A chamber lined with material that absorbs radio-frequency radiation: An RF-exposure system free of scattered and reflected radiation.

ANTENNA A device for radiating or receiving radio waves.

CONTINUOUS WAVE (CW) Electromagnetic fields that vary sinusoidally in time; that is, those fields which oscillate at a single frequency.

CORE TEMPERATURE The temperature near the center of the body; usually measured in the rectum.

ELECTROMAGNETIC RADIATION (EMR) Energy in the form of electric and magnetic fields.

EXENCEPHALY A protrusion of the brain from the skull. Thought to be a failure of the skull to close during embryonic development.

FREQUENCY The number of sinusoidal cycles made by electromagnetic radiation in one second; usually expressed in units of hertz (Hz).

GIGAHERTZ (GHz) One billion cycles per second

HERTZ (Hz) One cycle per second

HYPERTHERMIA Extremely high temperatures

IN UTERO Within the uterus or womb

MEGAHERTZ (MHz) One million cycles per second

MICROWAVE A particular segment of the RF radiation spectrum with a frequency range of 300 MHz to 300 GHz.

NONIONIZING RADIATION Electromagnetic radiation of low frequency, long wavelength, and low photon energy, unable to cause ionization.

ORGANOGENESIS The development or growth of organs, especially embryologic.

PARAMETER Any of a set of physical properties whose values determine the characteristics or behavior of something.

PLANE WAVE An electromagnetic wave in which the electric and magnetic field vectors lie in a plane perpendicular to the direction of wave propagation.

POWER DENSITY Magnitude of the Poynting vector at a point in space, in power per unit area (watts per square meter). For plane waves E^2 is simply related to power density, and it is the quantity measured by a survey meter when the sensing element is sensitive to the square of the magnitude of the electric fields;

RADIATION The transfer of energy from one body to another through an intervening medium.

RADIOFREQUENCY RADIATION (RFR) Nonionizing electromagnetic radiation in the frequency range of 0 to 3000 GHz.

SPECIFIC ABSORPTION The absorbed energy in the tissue, in joules per kilogram (J/kg).

SPECIFIC ABSORPTION RATE (SAR) The rate at which energy is absorbed in the tissue, in watts per kilogram.

TERATOLOGY That division of embryology and pathology which deals with abnormal prenatal development and congenital malformations.

THERMAL EFFECT In the biological tissue or system, an effect that is related to heating of the tissue through the application of electromagnetic fields, and that can occur through other forms of heating.

THERMOREGULATION The maintenance of a particular temperature in the living body.